Moments of the neutron g_2 structure function and the novel extraction of higher-twist effects

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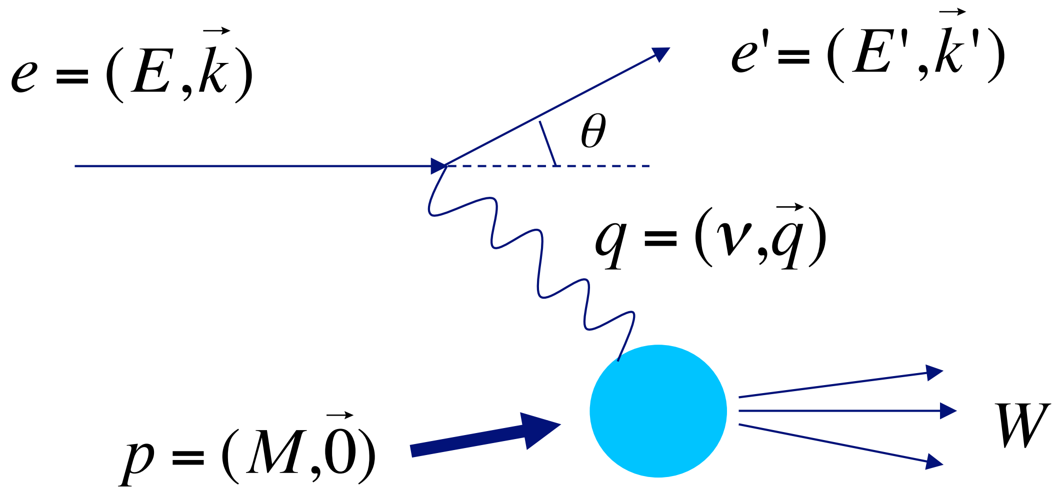
Inclusive Electron Scattering



<u>4-momentum transfer squared</u>

$$Q^2 = -q^2 = 4EE'\sin^2\tfrac{\theta}{2}$$

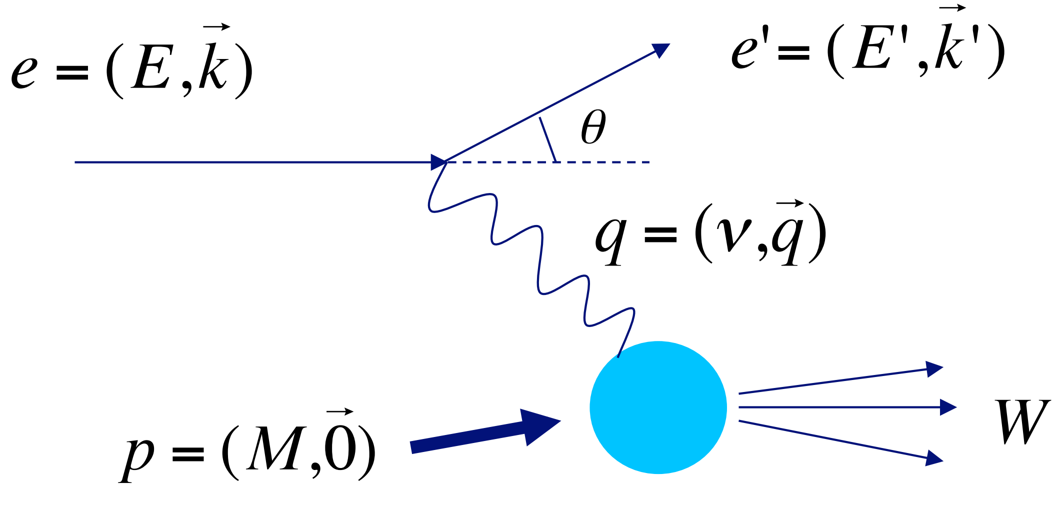
<u>Invariant mass squared</u>

$$W^2 = M^2 + 2M\nu - Q^2$$

<u>Bjorken variable</u>

$$x = \frac{Q^2}{2M\nu}$$

Inclusive Electron Scattering

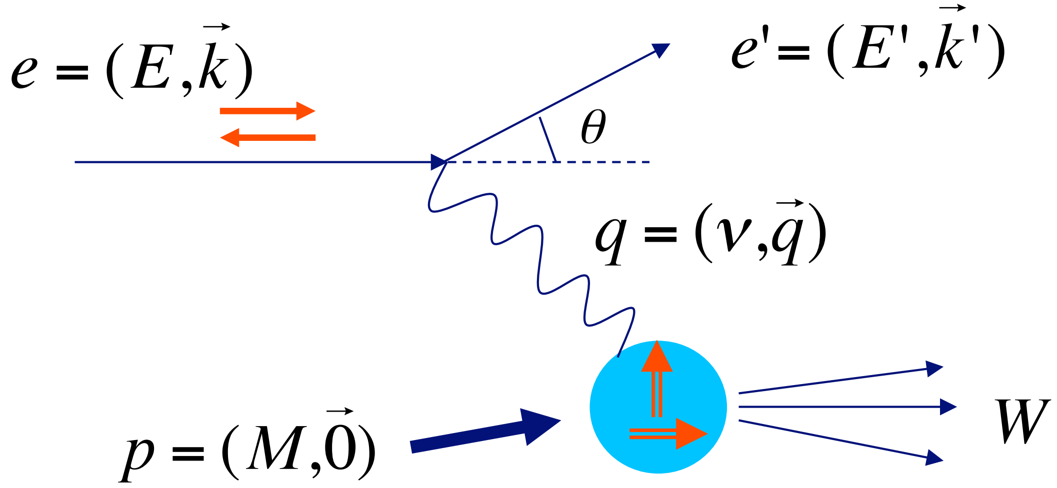


$$Q^2 = -q^2 = 4EE'\sin^2\tfrac{\theta}{2}$$

$$x = \frac{Q^2}{2M\nu}$$

Unpolarized case
$$\frac{d^2\sigma}{d\Omega dE'} = \sigma_{Mott}\left[\frac{1}{\nu}F_2(x,Q^2) + \frac{2}{M}F_1(x,Q^2)\tan^2\tfrac{\theta}{2}\right]$$

Inclusive Electron Scattering



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Polarized case

$$\frac{d^2\sigma^{\uparrow\Uparrow}}{d\Omega dE'} - \frac{d^2\sigma^{\downarrow\Uparrow}}{d\Omega dE'} = \frac{4\alpha^2 E'}{\nu E Q^2}\left[(E + E'\cos\theta)g_1(x,Q^2) - 2Mxg_2(x,Q^2)\right]$$

Operator Product Expansion

- Expansion of moments of structure functions in a power series of 1/ $Q^{(\tau-2)}$
- Twist-2: scattering off free quarks.
- Higher twist: quark-quark correlations, and quark gluon correlations.
- In g1 higher twist can be separated using a series of measurements over a large rage of Q2.
- In case of g2, leading-twist part can be calculated and separated out using Wandzura-Wilczek prescription:

$$g_2^{WW}(x,Q^2) \equiv -g_1(x,Q^2) + \int_x^1 y^{-1} g_1(y,Q^2)\,dy$$

- So the higher-twist component of g_2:

$$\overline{g_2}(x,Q^2) = g_2(x,Q^2) - g_2^{WW}$$

Twist-3 matrix element d_2

$$\tilde{d}_2(Q^2) = \int_0^1 dx\ x^2(2g_1 + 3g_2)$$

At high Q^2

$$\tilde{d}_2(Q^2) \rightarrow d_2$$

Caution: at low Q^2, target mass corrections of order M^2/Q^2 become important, however these are twist-2; need to be calculated and separated out.

Alternate approach: use Natchmann moments instead.

Hall A experiment E01-012

Spokespersons: N. Liyanage, J. P. Chen, S. Choi; PhD student: P. Solvignon

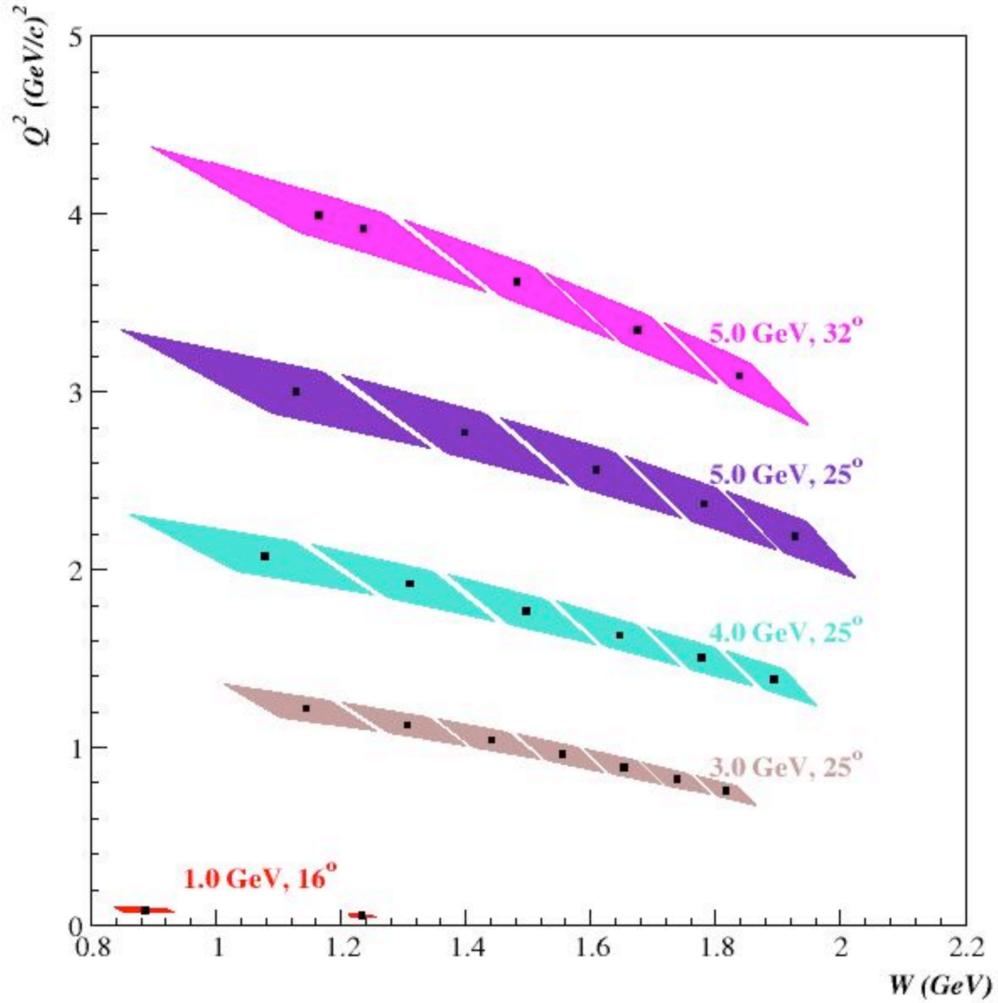
Ran in Jan.-Feb. 2003

- Inclusive experiment:

$$ {}^{3}\vec{He}(\vec{e},e')X $$

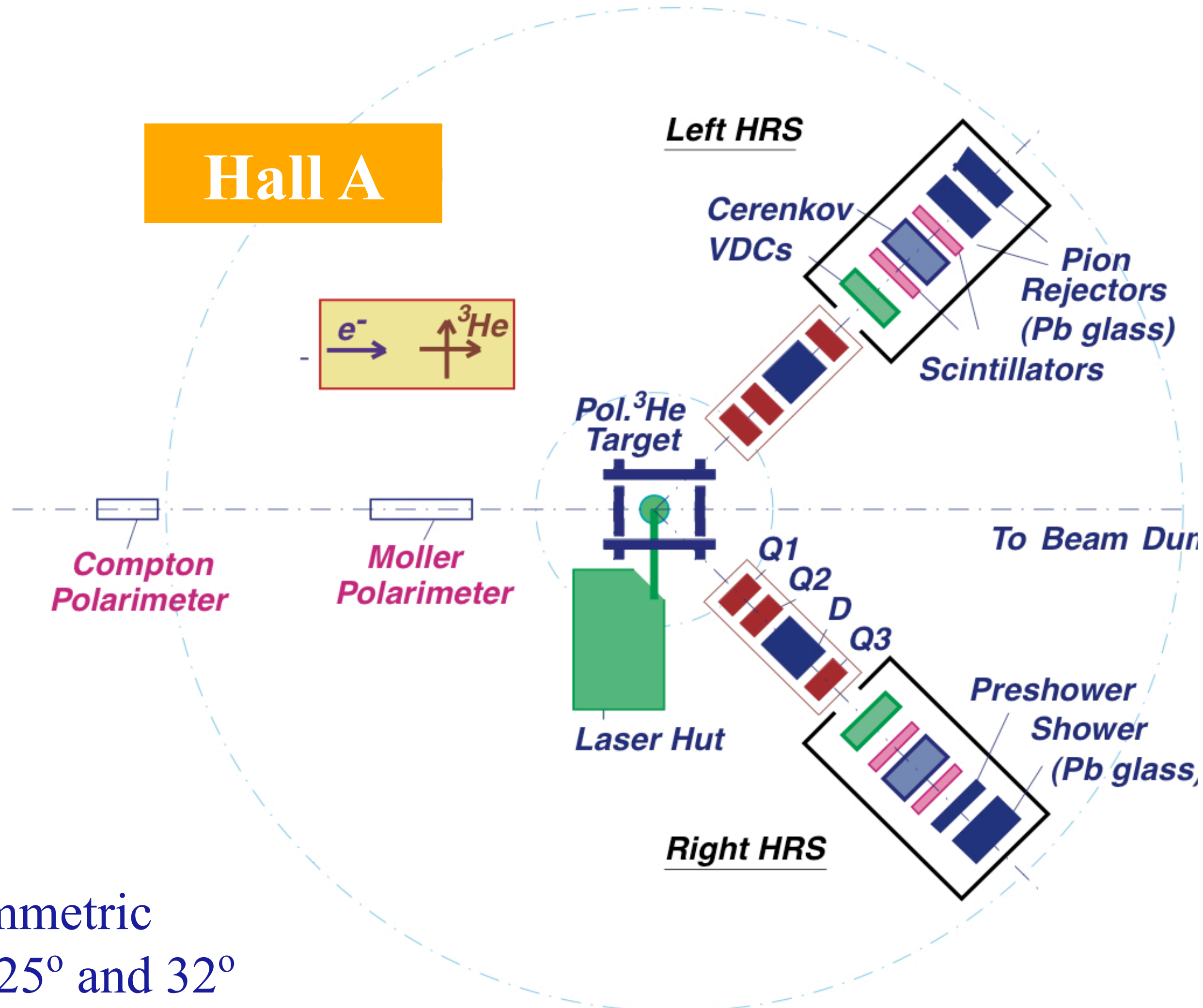
- Measured polarized cross section differences

- Form g_1 and g_2

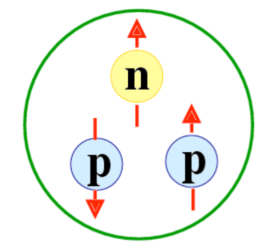


↪ **Test of spin duality on the neutron (and ^{3}He)**

Experimental setup



Polarized ^{3}He as an effective neutron target



^{3}He (s state)

Both HRS in symmetric configuration at 25° and 32°

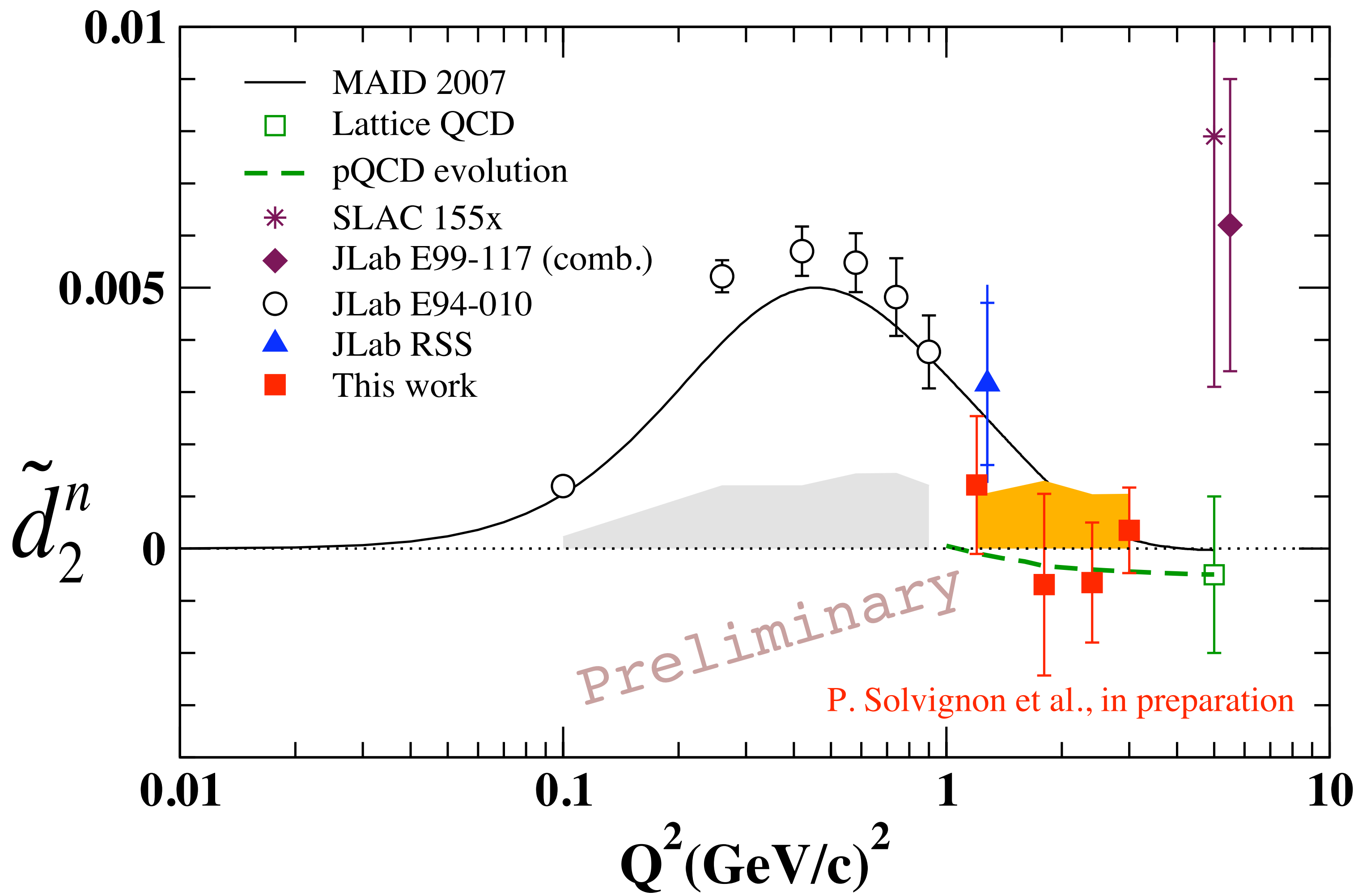
↪ double the statistics

↪ control the systematics

Particle ID = Cerenkov + EM calorimeter

↪ π/e reduced by 10^4

$\tilde{d}_2^n$ from E01-012



Moments from E01-012 and E94-010 include the resonance region only

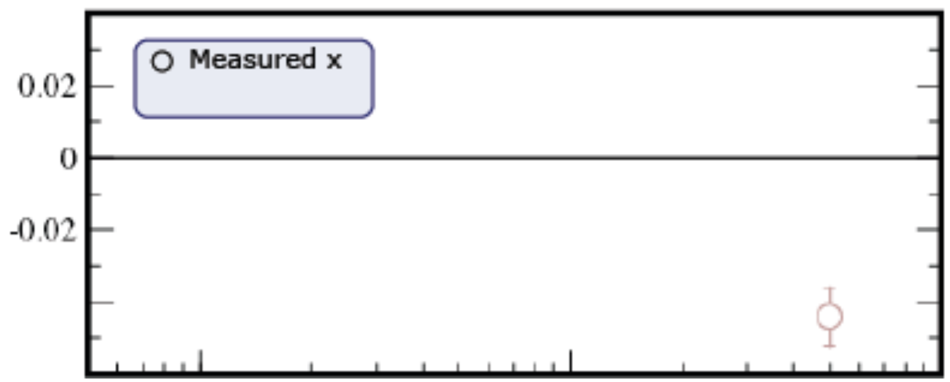
Burkhardt-Cottingham Sum Rule

$$\Gamma_2(Q^2) = \int_0^1 dx\, g_2(x,Q^2) = 0$$

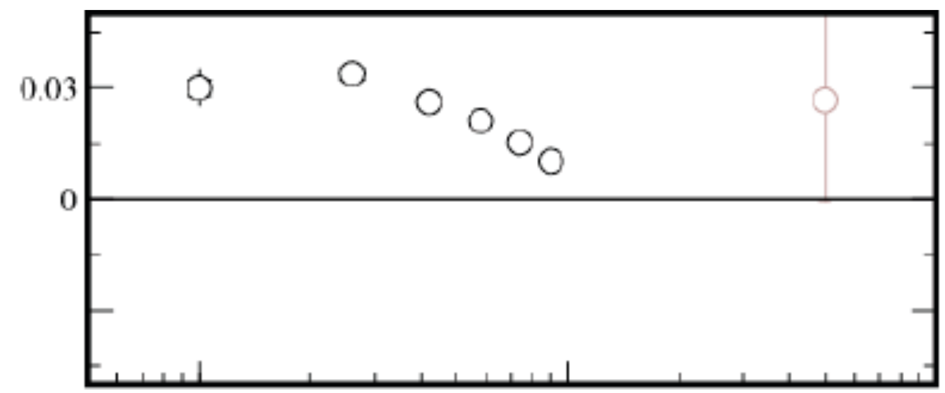
H.Burkhardt and W.N. Cottingham
Annals Phys. **56** (1970) 453.

- Based on the virtual compton amplitude S_2 going to zero faster than $1/\nu$.
- If holds at one Q^2, valid at all Q^2
- SLAC E155: violated for proton at ~ 2.5 sigma level, satisfied for neutron with a large error.
- Sum-rule satisfied for the leading twist part (g_2^{WW}) be definition; so if there is any violation, it is all due to higher-twist

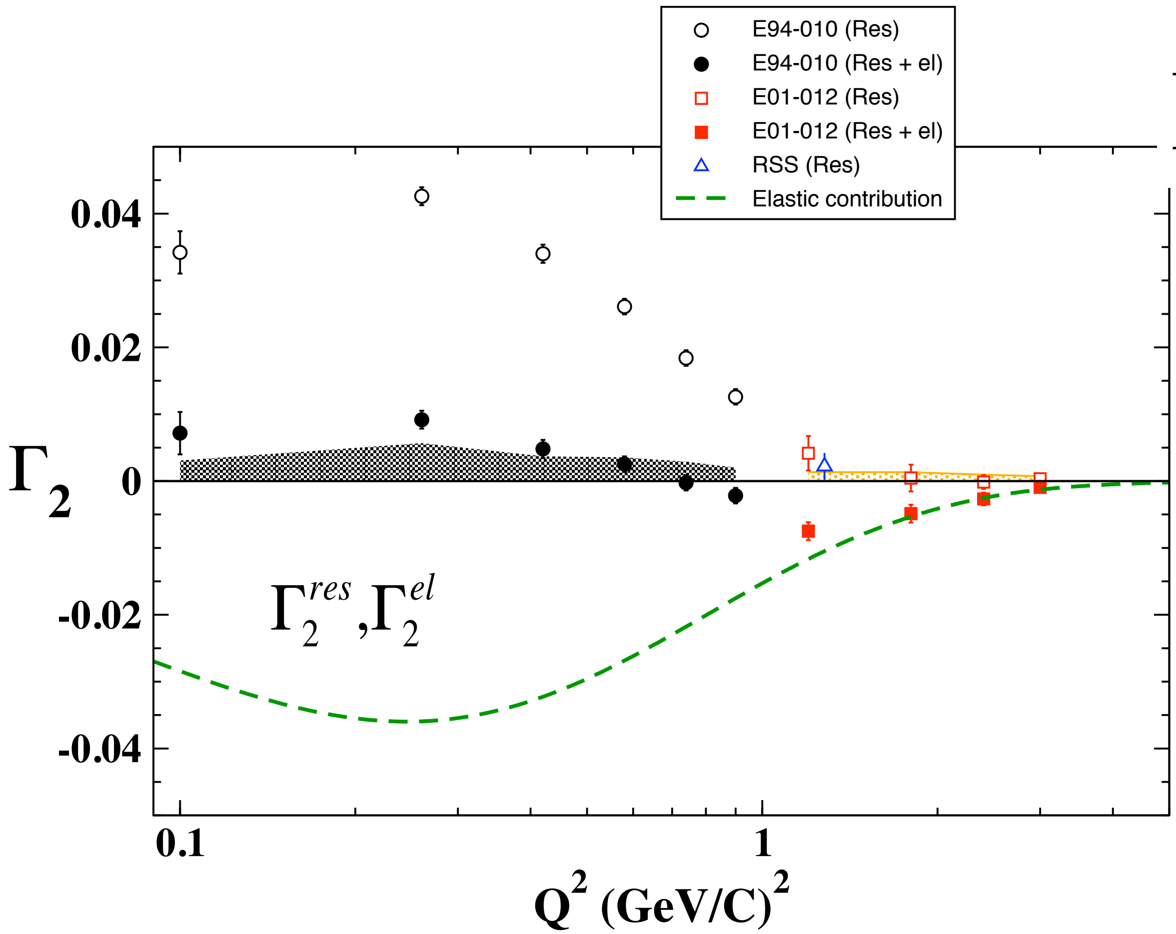
P



N



Γ_2^n from E01-012

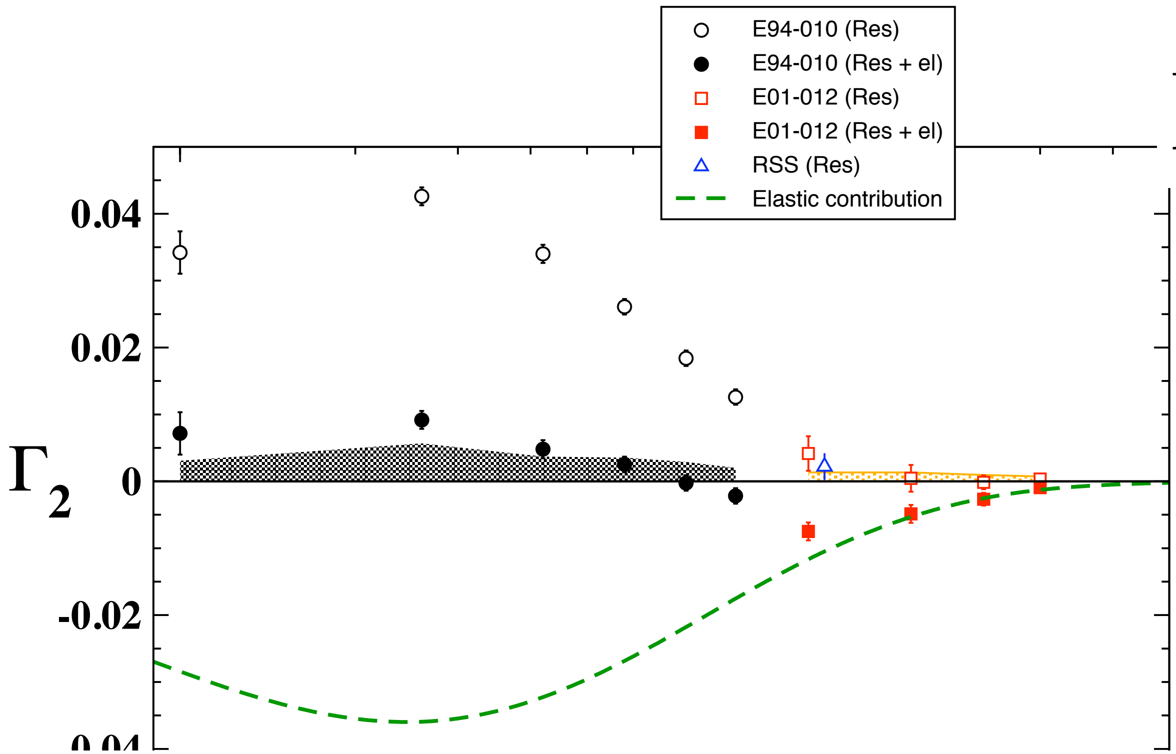


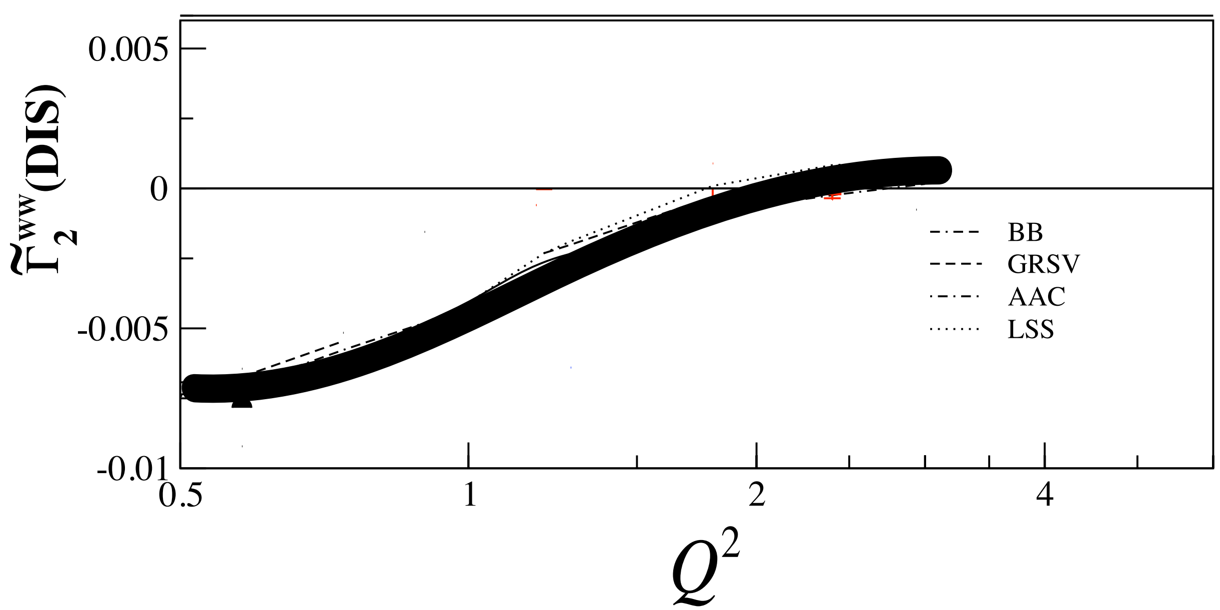
$$\Gamma_2 = \Gamma_2^{res} + \Gamma_2^{el} + \Gamma_2^{DIS}$$

But no data for Γ_2^{DIS}

We can use global NLO fits of g1 to determine $\Gamma_2^{WW,\,DIS}$

Γ_2^n from E01-012



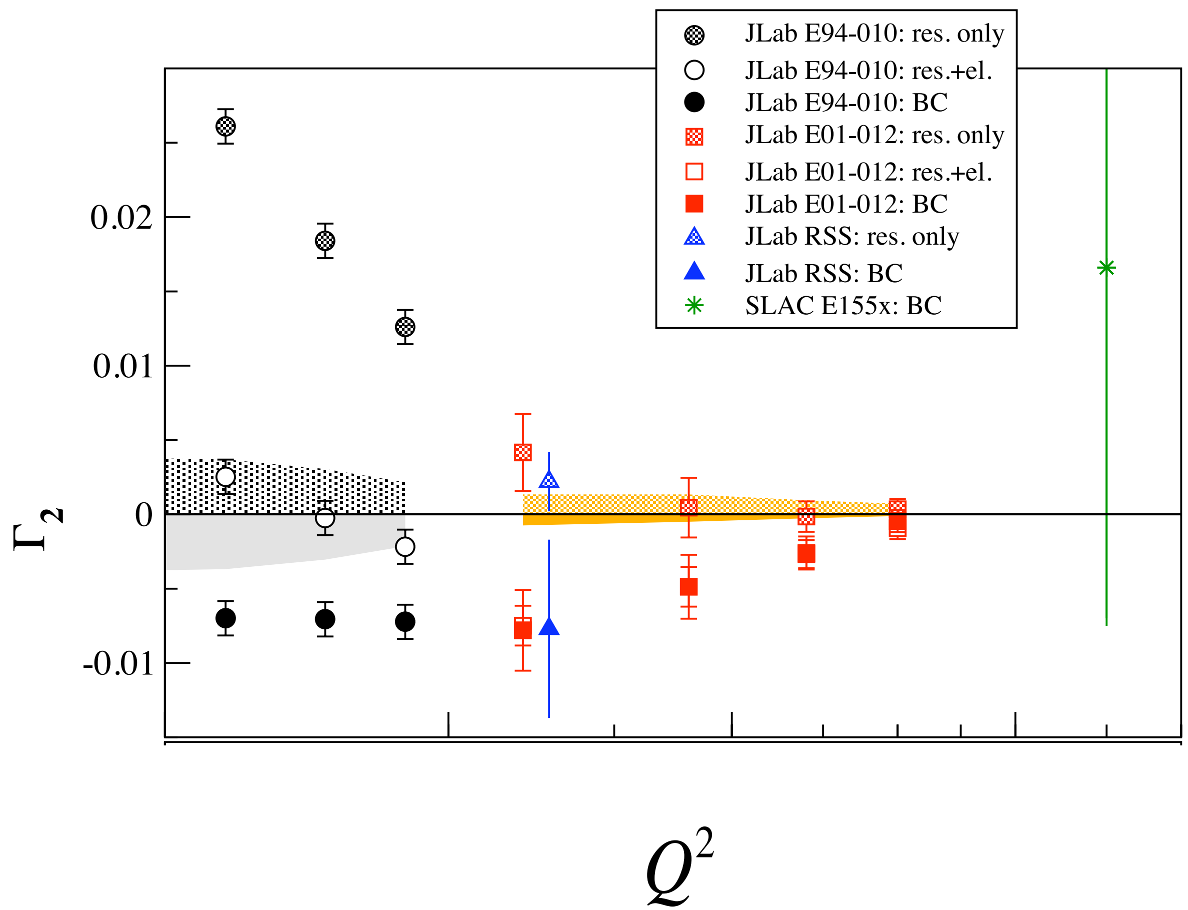


$$\Gamma_2 = \Gamma_2^{res} + \Gamma_2^{el} + \Gamma_2^{DIS}$$

$$= \underbrace{\Gamma_2^{res} + \Gamma_2^{el} + \Gamma_2^{WW,DIS}}_{\text{Known part}} + \overline{\Gamma}_2^{DIS}$$

unknown part

Γ_2^n from E01-012



Extracting the higher-twist part of Γ_2^{DIS}

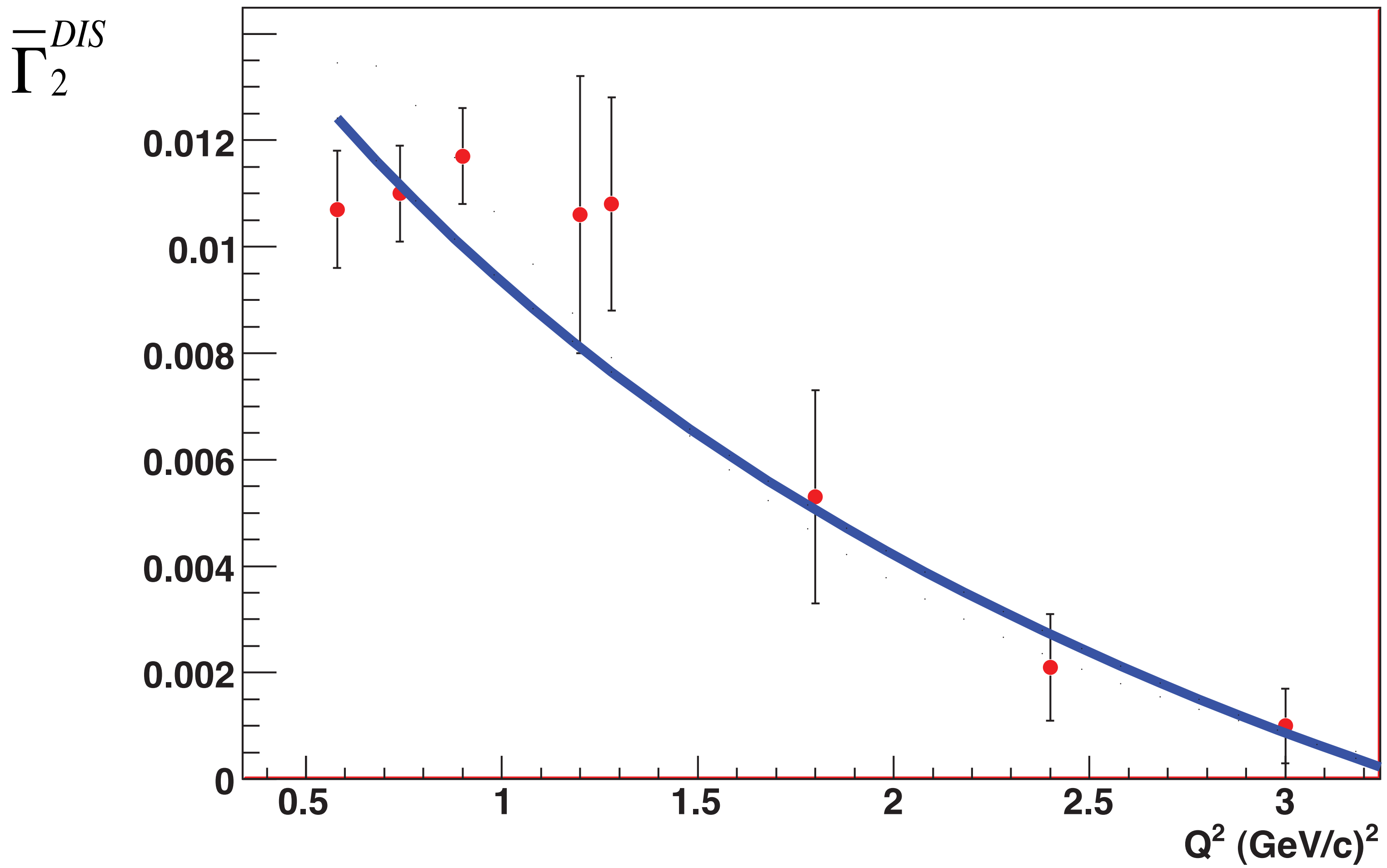
$$\Gamma_2 = \Gamma_2^{res} + \Gamma_2^{el} + \Gamma_2^{DIS}$$

$$= \underbrace{\Gamma_2^{res} + \Gamma_2^{el} + \Gamma_2^{WW,DIS}}_{\text{Known part}} + \overline{\Gamma}_2^{DIS}$$

unknown part:
Higher twist
part of DIS

$$\overline{\Gamma}_2^{DIS} = -\left(\Gamma_2^{res} + \Gamma_2^{el} + \Gamma_2^{WW,DIS}\right)$$

Extracting the higher-twist part of Γ_2^{DIS}



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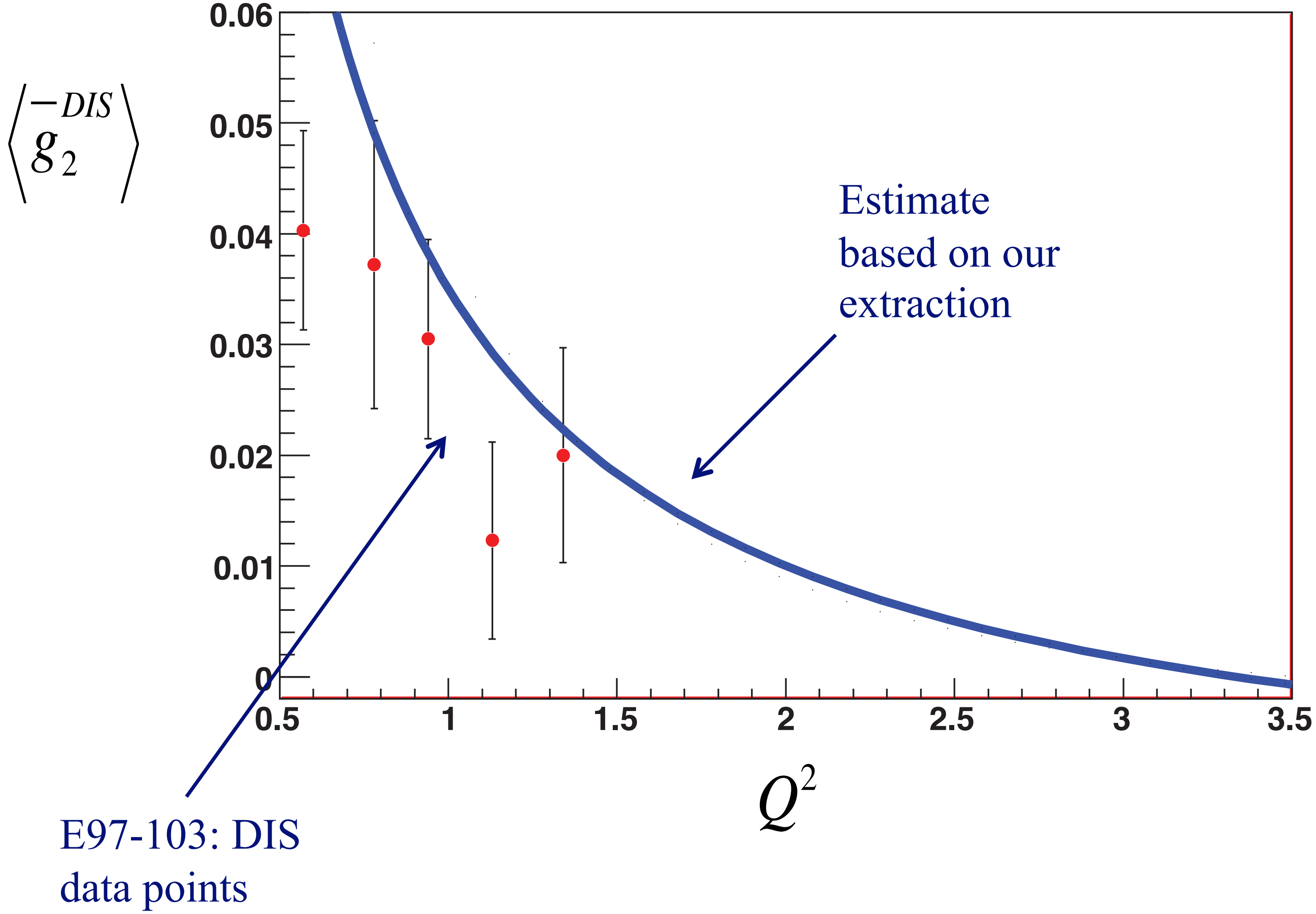

Summary

- E01-012 provides precision data of Spin Structure Functions on neutron (^{3}He) in the resonance region for $1.0<Q^2<4.0(\mathrm{GeV}/c)^2$ - Direct extraction of $g1$ and $g2$ from our data
- The resonance contribution to d_2^n becoming smaller and going to zero by about $Q^2 = 3\ \mathrm{GeV}^2$.
- Γ_2^n, evaluated without the higher-twist part from DIS is clearly not zero below $Q^2 \sim 2.5\ \mathrm{GeV}^2$.
- If we assume BC sum-rule as valid, can extract an the higher twist part of Γ_2: positive and large, may be as large as Γ_2^{WW}.
- Average $\left\langle \bar{g}_2^{DIS} \right\rangle$ extracted from our data seems to agree with previous DIS data
- Same method applied to the proton (RSS data) reveals no HT.